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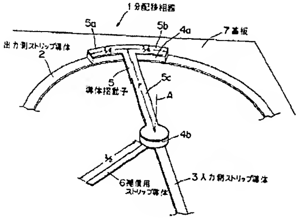
(54) [Title of the Invention] Distributed Phase Shifter

(57) [Summary]

[Structure] Circular arcuate slide elements 5a, 5b are slid by means of an insulator 4a along an output-side strip conductor 2 in which the two ends of a partially open circular ring serve as output terminals. A high frequency signal inputted from an input-side strip conductor 3 is distributed through an arm 5c in both directions of the output-side strip conductor 2 via the insulator 4a in the slide elements 5a, 5b, at a phase that corresponds to the rotation angle of the arm 5c, and the signal reaches the output terminals.

[Effects] The size and weight of the distributed phase shifter 1 can be reduced, and its manufacture can be simplified. Also, electrical distribution and phase shifting can be performed

with the same configuration, and therefore the number of components is reduced and reliability is improved in comparison with when they are performed separately.



Key

1	distributed phase shifter
2	output-side strip conductor
3	input-side strip conductor
5	conductor slide
6	impedance-compensating strip conductor
7	substrate

[Claims]

[Claim 1] A distributed phase shifter, comprising:

an output-side strip conductor in the form of a partially open circular ring, with the two ends serving as output terminals;

an input-side strip conductor wherein one end is positioned at the center of the radius of the circular ring; and

a conductor slide having arcuate slide elements whose radius is substantially equal to the radius of the circular ring, and an arm whose length is substantially equal to the radius of the circular ring that extends perpendicularly towards the center of the curvature from the center of the slide elements, characterized in that:

the distal end of the arm is allowed to rotate around the center of the radius of curvature of the circular ring; and

insulators are located between the output-side strip conductor and the arcuate sliding members, and between the input-side strip conductor and the arm.

[Claim 2] The distributed phase shifter according to claim 1, characterized in that an impedance-compensating strip conductor is added to part of the input-side strip conductor.

[Detailed Description of the Invention]

[0001]

[Technological Field of the Invention] The present invention relates to a distributed phase shifter that can perform electrical distribution of high frequency signals, and that can continuously vary the phase of the distributed signals. This distributed phase shifter can be used to configure a variable-phase power supply that can continuously vary the beam tilt angle (orientation) of an array antenna.

[0002]

[Prior Art and Problems to Be Solved by the Invention] In order to vary the beam tilt angle of an array antenna, the length of a cable for supplying the high frequency signal distributed by the electricity distributor to the array antenna elements is varied, whereby the phase distribution of a high frequency electrical current supplied to the array antenna is varied.

[0003] When the amount of the phase shift is to be changed with a power supply that uses such a cable; for example, when the power supply is to be installed outdoors, an operation must be performed that requires a procedure in which the waterproof section is removed and the cable is taken out of the connector, replaced with a cable of different length or is cut and shortened, again mounted on the connector, and waterproofed.

[0004] Also, in order to change the beam tilt angle of the array antenna, the same length of cable is used, and a phase converter is inserted between an electricity distributor and the array antenna. A power supply that uses this phase converter requires multiple switches and cables to vary the phase either continuously or at a small pitch, which leads to an increase in dimensions and in costs. Moreover, since the switches have mechanical contact points, it is possible that contact failures will occur due to changes over time, which can cause intermodulation or noise generation.

[0005] In view of this, an object of the present invention is to solve the technical problems described above, and to provide a distributed phase shifter that can continuously vary the phase by means of a simple and highly reliable structure.

[0006]

[Means Used to Solve the Above-Mentioned Problems] In order to achieve the aforementioned objectives, the distributed phase shifter according to claim 1 comprises an output-side strip conductor in the form of a partially open circular ring, with the two ends serving as output terminals; an input-side strip conductor wherein one end is positioned at the center of the radius of the circular ring; and a conductor slide having arcuate slide elements whose radius is substantially equal to the radius of the circular ring, and an arm whose length is substantially equal to the radius of the circular ring that extends perpendicularly towards the center of the curvature from the center of the slide elements; wherein the distal end of the arm is allowed to rotate around the center of the radius of curvature of the circular ring, and insulators are located between the output-side strip conductor and the arcuate sliding members, and between the input-side strip conductor and the arm.

[0007] The distributed phase shifter may have an impedance-compensating strip conductor added to part of the input-side strip conductor (claim 2).

[0008]

[Operation of the Invention] According to the configuration in claim 1, electric power can be distributed because the high frequency signal inputted from the input-side strip conductor is transmitted to the conductor slide, then is distributed in both directions of the output-side strip conductor via the conductors in the slide elements, and is allowed to reach the output terminals. Also, since the positions of the slide elements and to the distance to the two output terminals of the output-side strip conductor is determined by the rotation angle of the arm, the positions of the slide elements and the distance to both output terminals of the output-side strip conductor can be varied by rotating the arm. Therefore, the phase difference between the high frequency signals that reach the output terminals of the output-side strip conductor can be freely adjusted.

[0009] Also, according to the invention in claim 2, it is possible for the input-side strip conductor to compensate for and to adjust the electrostatic capacitance between the conductor and the ground.

[0010]

[Working Examples] The present invention is described in detail below with reference to the accompanying diagrams showing the working examples. Fig. 1 is a perspective view of a distributed phase shifter 1 relating to a working example. In the distributed phase shifter 1, a long and thin input-side strip conductor 3 and an partially open annular output-side strip conductor 2 are set on a dielectric substrate 7, and one end of the circular shape of the input-side strip conductor 3 is disposed in the center of the circular ring (center axis indicated by A) of the output-side strip conductor 2. Furthermore, an impedance-compensating strip conductor 6 with a length $\lambda/2$ (λ indicates wavelength) branches off from the input-side strip conductor 3 at one end of the circular shape of the input-side strip conductor 3. The impedance-compensating strip conductor 6 is inductive in order to compensate for the electrostatic capacitance created between the end of the input-side strip conductor 3 and the ground. Also, an anchor-shaped conductor slide 5 is provided, and one end (for example, the section connected to the anchor cable) of the primary axis of the anchor (hereinafter referred to as the "arm") 5c is disposed to be capable of rotating around the center axis A of the circular ring. The lengths of the sections corresponding to the left and right hooks of the anchor, or, specifically, the sections (hereinafter referred to as "slide elements") 5a, 5b that slide over the output-side strip conductor 2, are $\lambda/4$ both to the left and right. Also, high dielectric insulators 4a, 4b, which are insulating materials made of polyfluoroethylene or other material commonly used for high frequency electric wires, are located between the conductor slide 5 and the input-side strip conductor 3, and between the conductor slide 5 and the output-side strip conductor 2.

[0011] The width of the input-side strip conductor 3 is selected so that the characteristic impedance is 50 Ω, for example, and the width of the output-side strip conductor 2 is selected so that the characteristic impedance is 100 Ω. Due to this structure, the high-frequency signals inputted from the input-side strip conductor 3 are sent to the arm 5c of the conductor slide 5 via the high dielectric insulator 4b, and are passed through the arm to reach the left and right slide elements 5a, 5b on the distal end. The signals are then sent by the left and right slide elements 5a, 5b to the output-side strip conductor 2 via the high dielectric insulator 4a. A moderate amount of inductance is provided to the arm 5c, and the impedance is matched in resonance with the reactance component based on the high dielectric insulators 4a, 4b. Parallel flat transmission paths that are insulated by the high dielectric insulator 4a are formed on the left and right slide

elements 5a, 5b, and the lengths of both transmission paths are $\lambda/4$; therefore, the arm 5c of the conductor slide 5 and the output-side strip conductor 2 are connected to the center of the slide elements 5a, 5b in equivalent manner.

[0012] The impedance of the output-side strip conductor 2 as seen from the arm 5c of the conductor slide 5 is 50 Ω, because two output-side strip conductors 2 with a characteristic impedance of 100 Ω are connected in series. Therefore, the impedance matches on both the input and output sides. Assuming the propagation wavelength of the output-side strip conductor 2 is $\lambda\varepsilon$ and the radius of the arm is r, if the conductor slide 5 is rotated to the left by an angle θ from the center position, then the output phase δ_L of the left output-side strip conductor 2 is:

$$\delta_L = (2\pi / \lambda\varepsilon)\, r\theta$$

and the output phase δ_R of the right output-side strip conductor 2 is:

$$\delta_R = -(2\pi / \lambda\varepsilon)\, r\theta.$$

[0013] Therefore, when a constant phase difference δ is to be achieved using the distributed phase shifter 1, the conductor slide 5 should be turned by an angle that satisfies the formula

$$\theta = \lambda\varepsilon\delta / 4\pi r.$$

The four-way distribution variable-phase power supply comprises three of the distributed phase shifters 1 (referred to as the first, second, and third distributed phase shifters), and a diagram of the connecting circuits thereof is shown in Fig. 2. Specifically, the end 11 of the input-side strip conductor 3 of the first distributed phase shifter 1a is the receiving end, and both ends of the annular output-side strip conductor 2 of the first distributed phase shifter 1a are connected to the ends of the input-side strip conductors 3 of the second and third distributed phase shifters 1b and 1c. Furthermore, both ends of the annular output-side strip conductor 2 of the second distributed phase shifter 1b are respectively connected to the supplying ends 12 and 13, and both ends of the annular output-side strip conductor 2 of the third distributed phase shifter 1c are respectively connected to the supplying ends 14 and 15.

[0014] In the four-way distribution variable-phase power supply described above, the conductor slide of the first distributed phase shifter 1a should be rotated by an angle 2θ, and the conductor slides of the second and third distributed phase shifters 1b and 1c should both be rotated by an angle θ when an output phase difference is to be provided at a constant gradient to the terminals 12, 13, 14, and 15; for example, when the objective is to obtain outputs with phases of

3δ, δ, $-\delta$, and -3δ. Thus, the four-way distribution variable-phase power supply of the previous working example can continuously vary the electricity supplying phases of the terminals while equally distributing the electricity of the input high frequency signal four ways, whereby the beam tilt angle of the array antenna supplied with electricity can be continuously varied. Also, since there is no metal contact with the sliding sections, the occurrence of noise or intermodulation due to sliding can be prevented.

[0015] Next, the method of adjusting the impedance will be described. When a multiple-distribution variable-phase power supply is configured using a plurality of the distributed phase shifters 1, the phase on the output side is difficult to adjust because the characteristic impedances of the output-side strip conductors 2 increase according to the number of conductors. Therefore, the following technique is used to adjust the impedance on the input side.

[0016] In Fig. 3, a 50 Ω line L1 is used on the input side, and an impedance transformer L2 with a length of $\lambda/4$ is inserted. The impedance of the impedance transformer L2 should be selected such that:

$$(25 \times 50)^{1/2} = 35\ \Omega$$

In Fig. 4, 100 Ω lines are used as output-side strip conductors L3 and L6, and impedance transformers L4 and L7 with lengths of $\lambda/4$ are connected. The impedance of the impedance transformers L4 and L7 should be selected such that the following is true:

$$(50 \times 100)^{1/2} = 70\ \Omega.$$

[0017] The present invention has been described based on the working example above, but the present invention is not limited to this working example. For example, the lengths of the left and right slide elements 5a, 5b, on which parallel and level transmission paths that are insulated by the high dielectric insulator 4a are formed, may be selected from $3\lambda/4$, $5\lambda/4$, or the like, in addition to $\lambda/4$. Various other modifications can be made insomuch as they do not deviate from the scope of the present invention.

[0018]

[Effect of the Invention] According to the distributed phase shifter in claim 1 as described above, since the distributed phase shifter can be configured using a strip line or the like, the size and weight can be reduced, and its manufacture can be simplified. Also, since electricity distribution and phase shifting are performed with the same configuration, the number of

components is reduced and reliability is improved in comparison with when they are performed separately. Furthermore, the occurrences of contact failures and the like are rare, because there are no metallic contact points.

[0019] Also, if the distributed phase shifter is used to configure a variable-phase power supply, it is extremely efficient as an power supply for a mobile communication base station antenna or another such array antenna whose service area must be changed as needed. According to the distributed phase shifter in claim 2, an impedance-compensating strip conductor is added to part of the input-side strip conductor, making it possible for the input-side strip conductor to compensate for and to adjust the electrostatic capacitance between the conductor and the ground, and losses in distribution can therefore be prevented.

[Brief Description of the Drawings]

[Figure 1] A main perspective view of the distributed phase shifter relating to the working example

[Figure 2] A connection diagram of a variable-phase power supply configured by three distributed phase shifters

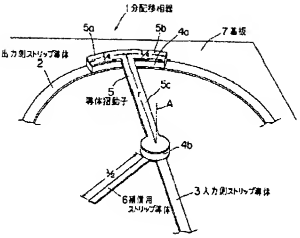
[Figure 3] A connection diagram of a distributed phase shifter in which the impedance on the input side has been adjusted using an impedance transformer

[Figure 4] A connection diagram of a distributed phase shifter in which the impedance on the output side has been adjusted using an impedance transformer

[Explanation of Symbols]

1	distributed phase shifter
2	output-side strip conductor
3	input-side strip conductor
4a, 4b	high dielectric insulator
5	conductor slide
6	impedance-compensating strip conductor

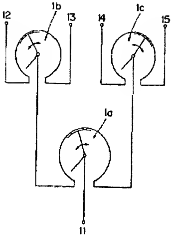
[Fig. 1]



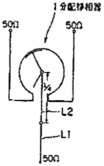
[Key]

1	distributed phase shifter
2	output-side strip conductor
3	input-side strip conductor
5	conductor slide
6	impedance-compensating strip conductor
7	substrate

[Fig. 2

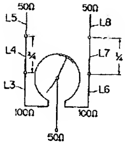


[Fig. 3]



[Key]

1 distributed phase shifter



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CERTIFICATION

The following document was translated by OSTRANS, LLC from the Japanese original into English:

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It represents an accurate and complete English translation of the original Japanese-language document to the best of our ability and belief.

Hiromi Tanimoto
April 25, 2005

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